BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: Astronaut Visibility of Features from the Lunar Surface - Case 710

DATE: January 19, 1968

FROM: A. F. H. Goetz

ABSTRACT

The maximum range of visibility of several objects of geologic interest is calculated and plotted as a function of height-of-eye, sun angle, azimuth and slope. It is shown that increasing the astronaut's height-of-eye, e.g., from the lunar surface to the LM ascent stage, significantly increases the detection range of rimless craters. For positive features, such as crater rims and blocks, visibility is determined mainly by the distance to the horizon and is otherwise independent of height-of-eye. In all cases, visibility is greater facing the sun than facing away from the sun. It is concluded that most objects of interest will be visible out to the astronauts' 1 km radius-of-action.

(NASA-CR-93417) ASTRONAUT VISIBILITY OF FEATURES FROM THE LUNAR SURFACE (Bellcomm, Inc.) 12 p

N79-73388

Unclas
00/91 12635

FF No. 602
CR-93417
(NASA CR OR TMX OR AD NUMBER)
15
(CATEGORY)

BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: Astronaut Visibility of Features from the Lunar Surface - Case 710

DATE: January 19, 1968

FROM: A. F. H. Goetz

MEMORANDUM FOR FILE

I. INTRODUCTION

In order to be able to plan a lunar surface geologic mission and to evaluate the utility of maps and photomosaics, the visibility of geologically interesting features must be established. This paper deals with the visibility, from the lunar surface and from the LM platform or roof,* of both negative and positive features as a function of contrast and size. Maximum ranges of perception are plotted for several examples.

II. CRITERIA AND ASSUMPTIONS

Visibility is a function of area and contrast. Under good lighting conditions (> 10 foot-lamberts) above a certain limiting angular size and within a contrast range, the contrast (C)x area (A) = Constant (K). This contrast constant, as well as other data related to human vision used in this paper, is given by Blackwell.[1] For a bright background there is also a limiting contrast of about .003 below which the eye does not detect an object against a background regardless of its area. Between contrast values of .003 and .01, (C)(A) is no longer constant. In this paper only contrasts in the range above $|C| = .01$ are considered. This threshold contrast was defined as the contrast which was detected with a probability of 50 per cent.

The lunar photometric function $\phi(\alpha,\tau)$ and the albedo define the brightness of the surface in the field of view. The angle α is the phase angle, or the angle between the sun and the viewing line, and τ is the angle between the viewing line and the normal to the surface projected into the phase plane. Figure 1 shows the geometry.

---

*The height-of-eye of an astronaut standing on the LM egress platform is approximately 5 m. The height-of-eye above the surface from the docking hatch in the LM roof is approximately 7 m. At the present time there is no plan to use either of these vantage points. However, for the purpose of demonstrating the advantage gained by increasing the height-of-eye, the 7 m elevation is used.

Contrast is defined as $C = \frac{\phi_1(\alpha,\tau_1)-\phi_0(\alpha,\tau_0)}{\phi_0(\alpha,\tau_0)}$

where $\phi_0(\alpha,\tau_0)$ is the brightness of the horizontal surface and $\phi_1(\alpha,\tau_1)$ is the brightness of the contrasting slope. The albedo is assumed to be constant. The contrast ranges from $C = -1$ for a shadow on a light surface to $+\infty$ for a bright spot on a shadowed surface.

The lunar photometric function used here, and shown in Figure 2, is given by Herriman <u>et al</u>[2] and is commonly known as the Fedorets function. A more detailed explanation of the various trigonometric relationships involved is given by Hamza[3]. For purposes of calculation a plane horizontal surface was assumed on which the objects of interest were superimposed and not obscured by other features. The features of interest were rimless craters, raised rim craters and blocks. From the standpoint of calculation, all other features of interest can be grouped with the above three.

III. COMPUTATION

A computer program was written to compute the visibilities. The main objective of the program was to calculate the greatest range at which the astronaut could detect a given object. The object was placed at the maximum limit of eye resolution (1/2 mr) and knowing its slope, the contrast with respect to the horizontal surface was calculated. If $(C)(A) < K$, the range was reduced and the contrast recalculated. If the contrast was found to be less than .01, the range was reduced in successive steps until the absolute value of the contrast became greater than .01. The three features mentioned above were handled in the following way:

1. Rimless Craters

Nearly rimless craters up to 30 meters in diameter are found on Orbiter photographs of mare regions. The maximum detectable range, assuming sufficient contrast, is given by the expression

$$r = -\frac{d}{2} + \sqrt{\frac{d^2}{4} + \frac{ad}{b}}$$

where r is the range, d is the crater diameter, a is the height of eye and b is the angular resolution of the eye. The fact that the range is inversely proportional to the square root of the angular resolution is a manifestation of the foreshortening phenomenon.

For low sun angles, shadows will be cast in the craters increasing the contrast to unity. James[4] has stated the criteria for the visibility of crater shadows assuming a conical crater profile. These criteria were incorporated in the program. Figures 3a-3d show the maximum distance at which an astronaut will be able to detect a one meter diameter rimless crater. Figures 4a and 4b show the advantage of increasing the height-of-eye to the LM roof. The contrast criteria were not applied to objects at lesser ranges and therefore certain visibility gaps at the zero phase washout points are not shown. The concentric circles denote distance from the observer and not angle, as is customary in a polar plot.

2. Raised Rim Craters

Raised rims are not subject to foreshortening, thus their detection range is proportional to their size and dependent on the slope. A value of .08 was assigned to the rim height-diameter ratio based on experimental explosion crater studies[5]. Rim slopes with values of 5° and 10° were used. In the latter case, for an astronaut on the ground, at a sun angle of 15° the rim of a 30 m crater is visible to the horizon, 2.4 km away in the 90°-180° quadrants. In this case the only advantage of increasing the height-of-eye is to extend the distance to the horizon. Figures 5a, 5b and 5c show the maximum distance at which raised rims of various sizes and slopes can be detected.

3. Blocks

The detection of blocks is of interest to lunar geologic EVA mission planners since one of the prime objectives is to sample basement material. The detection of blocks can be handled in the same manner as the raised rim craters. However, blocks, particularly fresh ones, do not exhibit a standard lunar type photometric function and generally have a higher albedo. This fact is very apparent on Surveyor pictures looking toward the horizon. Blocks are generally brighter than their surroundings and therefore exhibit high contrast. If the rock surfaces followed the standard surface photometric function, all visible block surfaces on the horizon having the same albedo as the surface would be darker than their surroundings. Since the contrast is high, the visibility of blocks will be dependent only on their angular size. A one meter block would therefore be visible at 2 km, or almost at the astronaut's ground-based horizon.

IV. CONCLUSIONS

The maximum distance at which representative objects of geologic interest can be detected has been calculated. In the case of rimless craters, increasing the astronaut's height-of-eye increases the detection range significantly. In the case of positive features such as crater rims and blocks, the visibility is determined mainly by the distance to the horizon and is otherwise independent of the height-of-eye. The visibility is in all cases greater in the 90°-180° quadrants, i.e., facing the sun rather than facing away from the sun.

The assumption of an uncluttered horizontal surface is, of course, artificial. Any nearby large crater would obscure features behind it. If the astronaut finds himself in a depression of any type, his horizon will be severely limited. The maximum values given may also be high because of unspecified form factors, such as the limit of resolution of the eye behind the helmet visor and the glare when facing the sun. However, the calculations presented here do give a good estimate of the visibility of geologically interesting features for an astronaut on the lunar surface.

A. F. H. Goetz

1012-AFHG-kse A. F. H. Goetz

REFERENCES

1. Blackwell, H. R., Contrast Thresholds of the Human Eye, J. Opt. Soc. Am. 36, 624 (1946).

2. Herriman, A. G., H. W. Washburn, and D. E. Willingham Jet Propulsion Laboratory Technical Report No. 32-384 (Rev), (1963).

3. Hamza, V., Lighting Conditions for a Lunar Landing Mission, Proceedings of the 4th Space Congress, Canaveral Council of Technical Societies, Cocoa Beach Fla., 17,1-17,23, April, 67.

4. James, D. B., Crater Shadow Visibility from the LEM, Bellcomm Memorandum for File, August, 20, 1965.

5. H. J. Moore, USGS (Private communication).

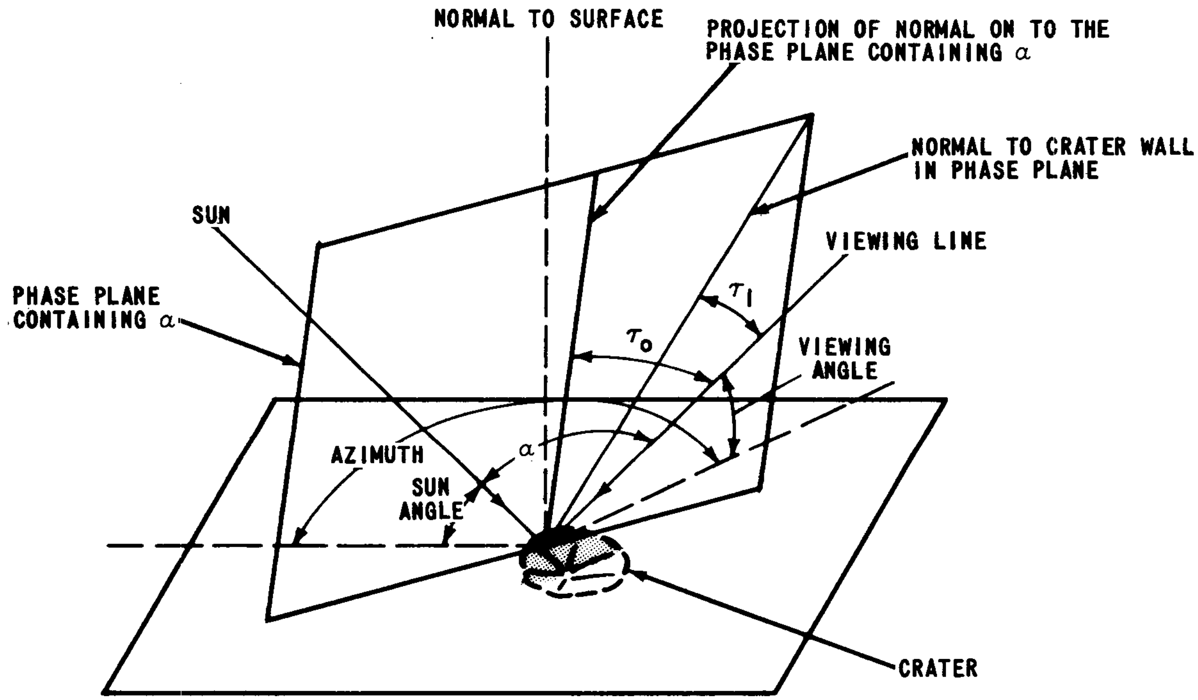


FIGURE 1 - GEOMETRIC RELATIONSHIPS PERTAINING TO CONTRAST CALCULATIONS

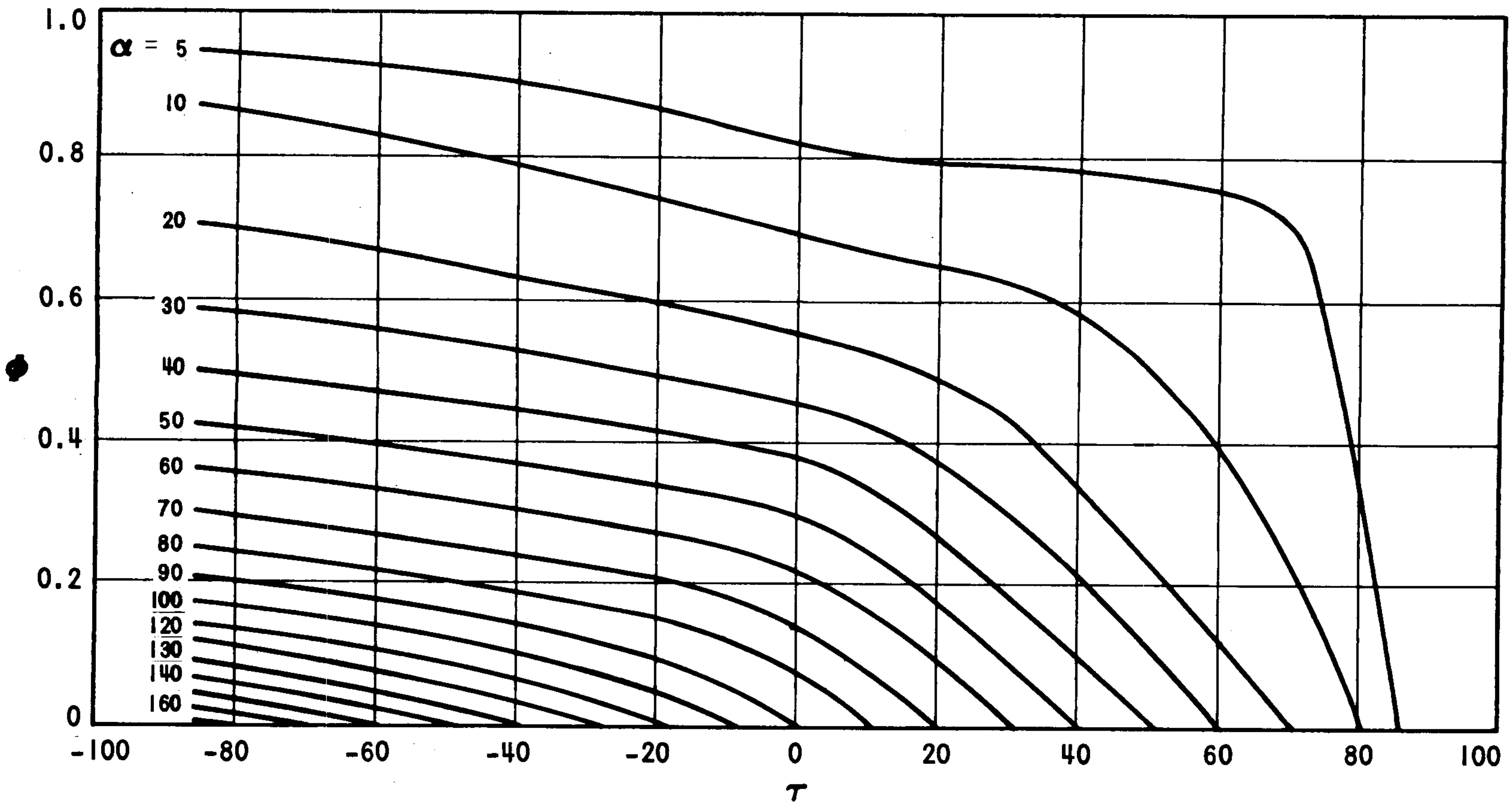


FIGURE 2 - PHOTOMETRIC FUNCTION Φ VERSUS ANGLE τ FOR DIFFERENT PHASE ANGLES α

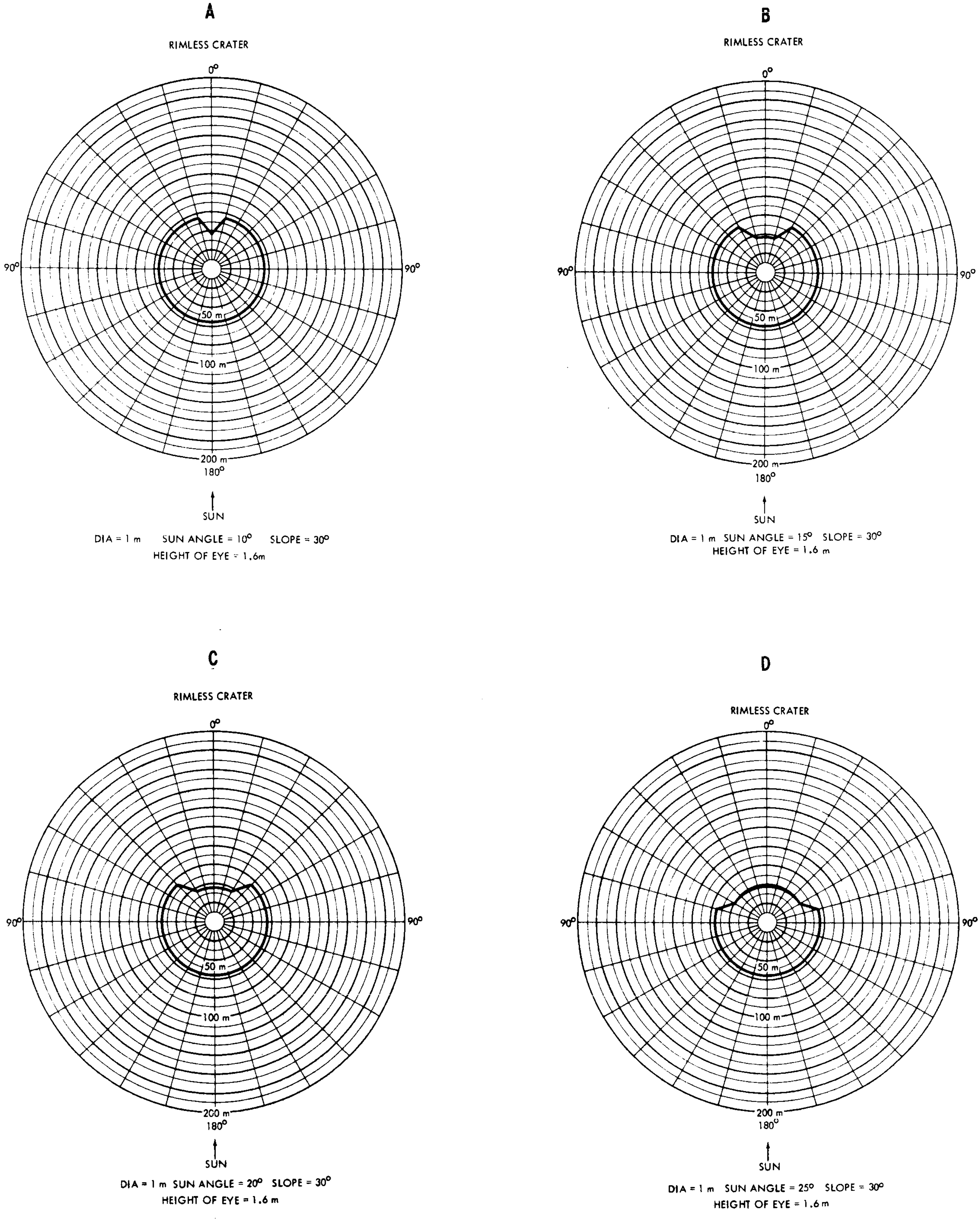
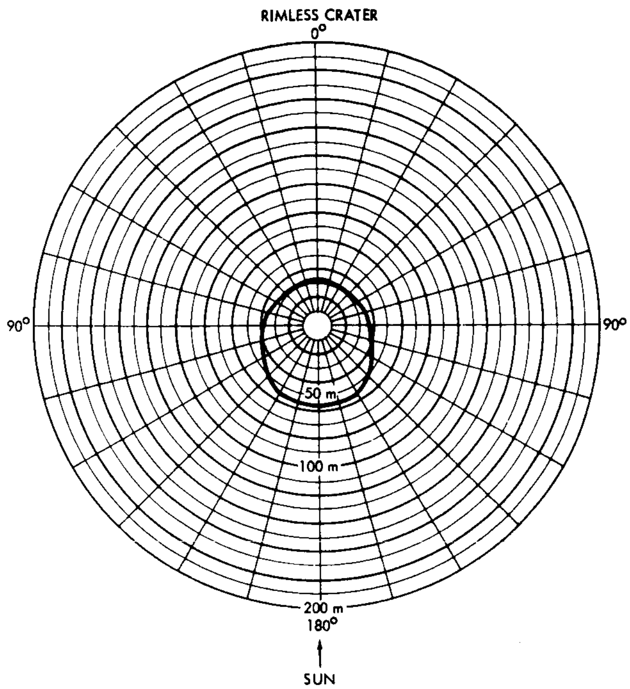


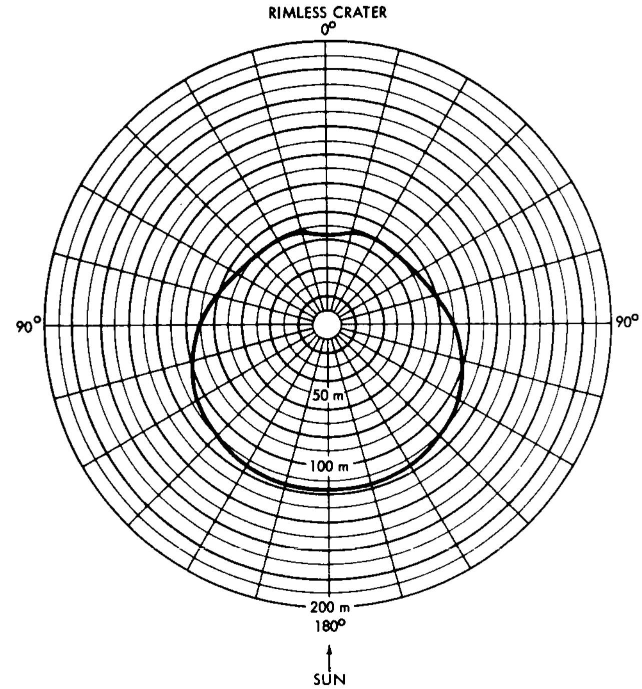
FIGURE 3 - THE MAXIMUM DISTANCE AT WHICH A 1 METER DIAMETER RIMLESS CRATER IS VISIBLE TO AN ASTRONAUT STANDING ON THE SURFACE

A



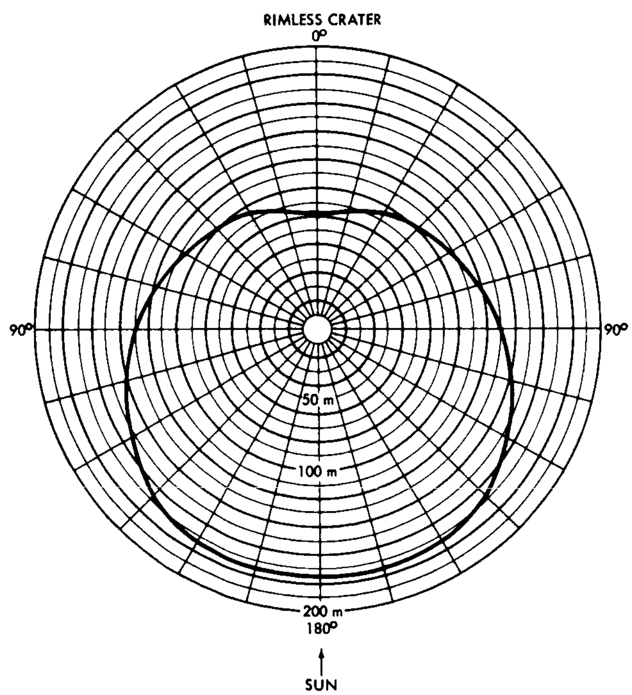
DIA = 1 m SUN ANGLE = 15° SLOPE = 10°
HEIGHT OF EYE = 1.6 m

B



DIA = 1 m SUN ANGLE = 15° SLOPE = 10°
HEIGHT OF EYE = 7 m

C



DIA = 10 m SUN ANGLE = 15° SLOPE = 10°
HEIGHT OF EYE = 1.6 m

FIGURE 4 - A,B, COMPARISON OF THE VISIBILITY OF A 1 METER DIAMETER RIMLESS CRATER FROM THE SURFACE AND FROM THE LM ROOF.
C, VISIBILITY OF A 10 METER DIAMETER RIMLESS CRATER FROM THE SURFACE

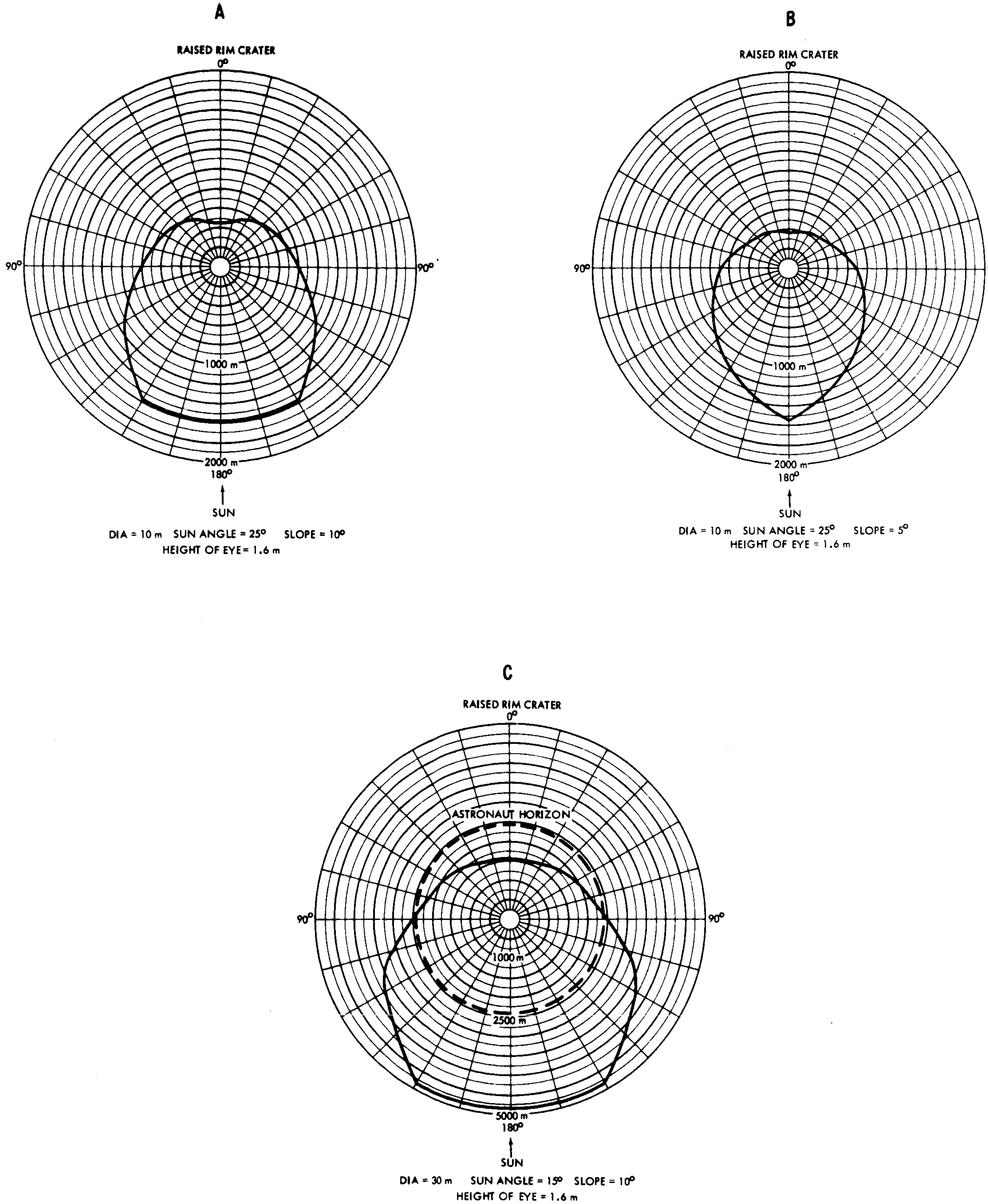


FIGURE 5 - THE MAXIMUM DISTANCE AT WHICH RAISED RIM CRATERS OF DIFFERENT SIZES AND SLOPES ARE VISIBLE FROM THE SURFACE

BELLCOMM, INC.

Subject: Astronaut Visibility of Features from the Lunar Surface

From: A. F. H. Goetz

Distribution List

NASA Headquarters

Messrs. W. A. Armstrong/MTX
R. J. Allenby, Jr./SL
D. A. Beattie/MTL
A. J. Calio/SY
P. E. Culbertson/MLA
E. M. Davin/SL
F. P. Dixon/MTY
R. J. Green/SL
P. Grosz/MTL
E. W. Hall/MTS
T. A. Keegan/MA-2
D. R. Lord/MTD
M. W. Molloy/SL
W. T. O'Bryant/SL
M. J. Raffensperger/MTE
L. Reiffel/MA-6
W. H. Rock/MLR
L. R. Scherer/SL
A. D. Schnyer/MTV
A. T. Strickland/SL
J. H. Turnock/MA-4
M. G. Waugh/MTP
V. R. Wilmarth/SL

Ames Research Center

Mr. L. Roberts/202-5 (2)

Manned Spacecraft Center

Messrs. J. W. Dietrich/TH2
J. E. Dornbach/TH3
J. M. Eggleston/TH
W. N. Hess/TA
M. V. Jenkins/FM
R. L. Jones/TH4
C. Klabosh/CF32
D. E. Lehr/CF32
J. P. Loftus/PD8
O. E. Maynard/PD
R. G. Rose/FA
J. H. Sasser/TH3
H. H. Schmitt/CB

Manned Spacecraft Center

Messrs. J. R. Sevier/PD12
L. C. Wade/TH3
R. J. Ward/PD12
R. G. Zedekar/CF32

U. S. Geological Survey

Messrs. N. G. Bailey
T. N. Karlstrom
H. Masursky
E. M. Shoemaker
D. E. Wilhelms

Bellcomm, Inc.

Messrs. F. G. Allen
G. M. Anderson
D. R. Anselmo
A. P. Boysen, Jr.
J. O. Cappellari, Jr.
J. P. Downs
D. R. Hagner
P. L. Havenstein
F. Heap
J. J. Hibbert
N. W. Hinners
W. C. Hittinger
B. T. Howard
D. B. James
K. E. Martersteck
R. K. McFarland
J. Z. Menard
V. S. Mummert
I. D. Nehama
G. T. Orrok
I. M. Ross
J. M. Tschirgi
R. L. Wagner
J. E. Waldo
All Members Division 101
Department 1023
Central File
Library